NOTE

A Modified Electronic Torsion Sensor for a 10-Gram Mixograph with Computerized Data Acquisition and Analysis

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A number of workers (Voisey et al 1966a,b; Voisey 1971; Rubenthaler and King 1986) replaced the mechanical (pen) torque recorder on the 10- and 35-g mixographs manufactured by the TMCO Company (Lincoln, NE) with electronic methods of monitoring the torque, both to save time and to measure the curve characteristics independent of operator judgment. Such methods increase the already established usefulness of the instrument (Harris et al 1943, Finney and Shogren 1972, Bruinsma et al 1978) as a quality control or research tool. An additional advantage to such electronic sensing is that the data acquired can be sent directly to a computer for processing and analysis. The object of this Note is to describe the electronic sensor modification we have devised to illustrate one approach to computerized manipulation of the data. At our laboratory, to sense the torque we incorporated a simple modification, which is different from those previously described. Sensing was accomplished by attaching a suitable linear, wire-wound potentiometer to the shaft of a 10-g instrument (Fig. 1). Since the initial testing, this potentiometer was replaced by a PLANAX rotary position sensor (Ominetrics/Biotronics Inc., Saddlebrook, NJ), which has no contacts, is linear, and has low friction. The output at zero torque was electronically adjusted to 0.00 mV and to 1,000.0 mV at full scale on the chart before mixing (the pen was usually raised from the paper). The output, proportional to the position of the bowl (i.e., torque), was sent to a mainframe computer (Modcomp Classic), although a personal computer with at least 640 K of random access memory could be used with appropriate software. Although we used the millivolt output as a measure of the torque, a calibration curve of the system with a weight-pulley arrangement (Voisey et al 1966a,b) is shown at a spring setting of 12 in Figure 2. Typical computer-generated curves are shown in Figure 3B–D. The 11 indicated parameters (Fig. 3D) chosen to test the modification and computer programming include those used by previous workers using pin-type mixers to classify wheats (Swanson and Johnson 1943).

The flours were not selected by design but were available from other studies. The variety, habit, and protein content were known.

A Pearson's correlation coefficient was calculated between each of the computerized mixograph measurements and both loaf volume and protein content (Table I). All correlations were significant ($P < 0.05$), with the exception of those including ART, ABP, and BW (Fig. 3D). Because of the close correlation ($r = 0.96$) between loaf volume and protein, a partial correlation analysis was run in order to estimate the correlation between the mixograph measurements and loaf volume independent of protein. After protein was held constant statistically, only EA, EH, and BW were correlated (P = 0.03, 0.04, and 0.07, respectively) with loaf volume. Thus the overall implication is that most of the differences in mixograph measurements in our test were due to differences in protein, although EA, BH, and BW may have been related to loaf volume through some factors in addition to protein. Two separate analyses of variance were run with mixograph measurements as response variables. In the first analysis, the effects of habit and variety within habit were measured, and in the second analysis the effects of protein (as

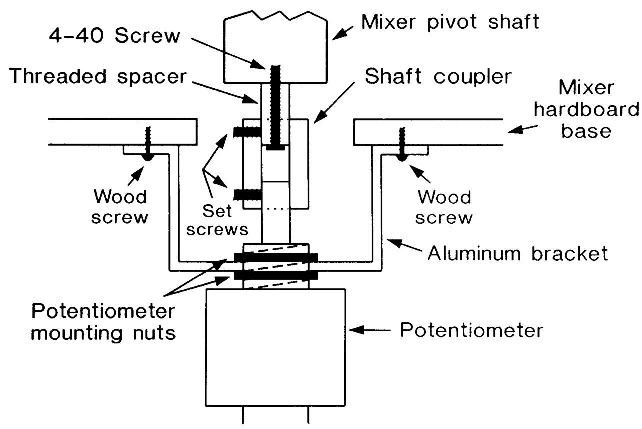

Fig. 1. Potentiometer mounting.

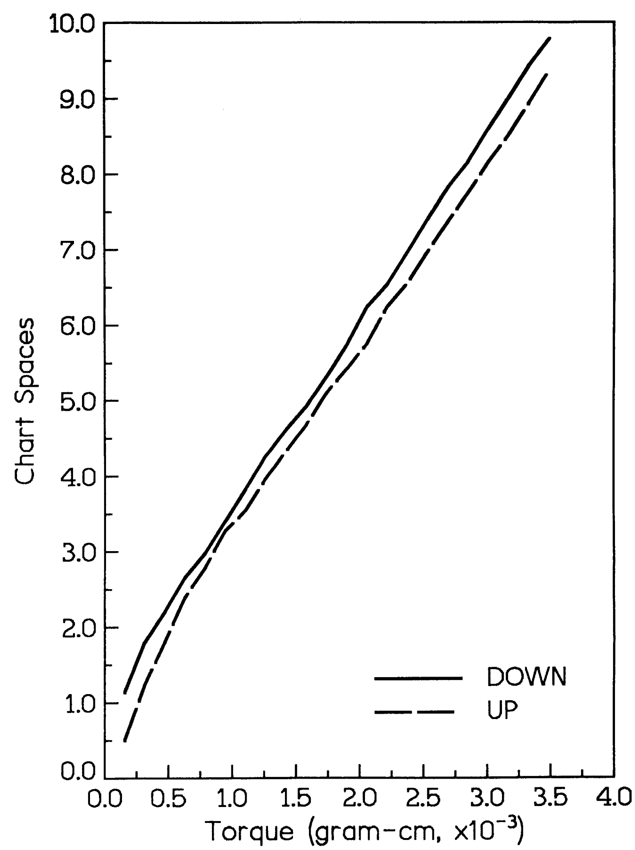

Fig. 2. Assembly calibration with weights and pulley. Torque versus chart spaces.

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TABLE I
Correlations Between Mixograph Measurements and Loaf Volume and Protein

	Correlations[b]		
Measurements[a]	Loaf Volume	Protein	Loaf Volume[c] Independent of Protein
PH	0.92	0.95	0.05
ART	−0.28	−0.35	0.19
A1	−0.59	−0.64	0.07
DEA	0.32	0.36	−0.10
PHMB	0.66	0.74	−0.27
ACA	0.60	0.63	−0.02
TA	0.90	0.94	0.03
EA	0.63	0.57	0.37
ABP	−0.06	−0.13	0.24
BH	0.85	0.83	0.35
BW	0.05	−0.05	0.31
BWP	0.58	0.56	0.18
ABPD	−0.41	−0.47	0.18

[a]Abbreviations explained in Fig. 3D, except for PHMB = PH minus BH (millivolts) and ABPD = ABP/TA (dimensionless).
[b]Correlations with absolute values larger than 0.42 are $P < 0.01$ and larger than 0.32 are $P < 0.05$ different from zero.
[c]Adjustments made by partial correlation procedures. Loaf volumes were determined by Truman Olson, North Dakota State University (*personal communication*).

a linear covariate) were included (Table II). The mean for the winter habit was different ($P < 0.05$) from the mean for the spring habit for all except the ABP and BW measures. Varieties within habit influenced ($P < 0.05$) both ABP and BW, however, as well as all the other measurements except for DEA and BWP. After the second analysis, the R^2 values were compared with those of the first analysis to determine the effect of adding protein to the model. For the PH, ACA, and TA measurements, adding protein to the model increased the R^2 value by more than 10 percentage points, but adding protein also caused habit and variety to be nonsignificant. Evidently, the effects of habit and variety on PH, ACA, and TA were due primarily to the protein differences among habit and variety. For A1, EA, and BH, adding protein to the model also increased the R^2 value by at least nine percentage points and also eliminated habit as a source of variation. Variety, however, had influences ($P < 0.05$) on A1, EA, and BH that were independent of protein and habit. For PHMB, protein was an influence ($P < 0.05$) along with habit and variety independently. Adding protein increased the R^2 by only three percentage points, so protein was evidently a factor in the first analysis through its effect on habit and variety. In the second analysis, the R^2 for BWP was increased by 14 percentage points, but no new

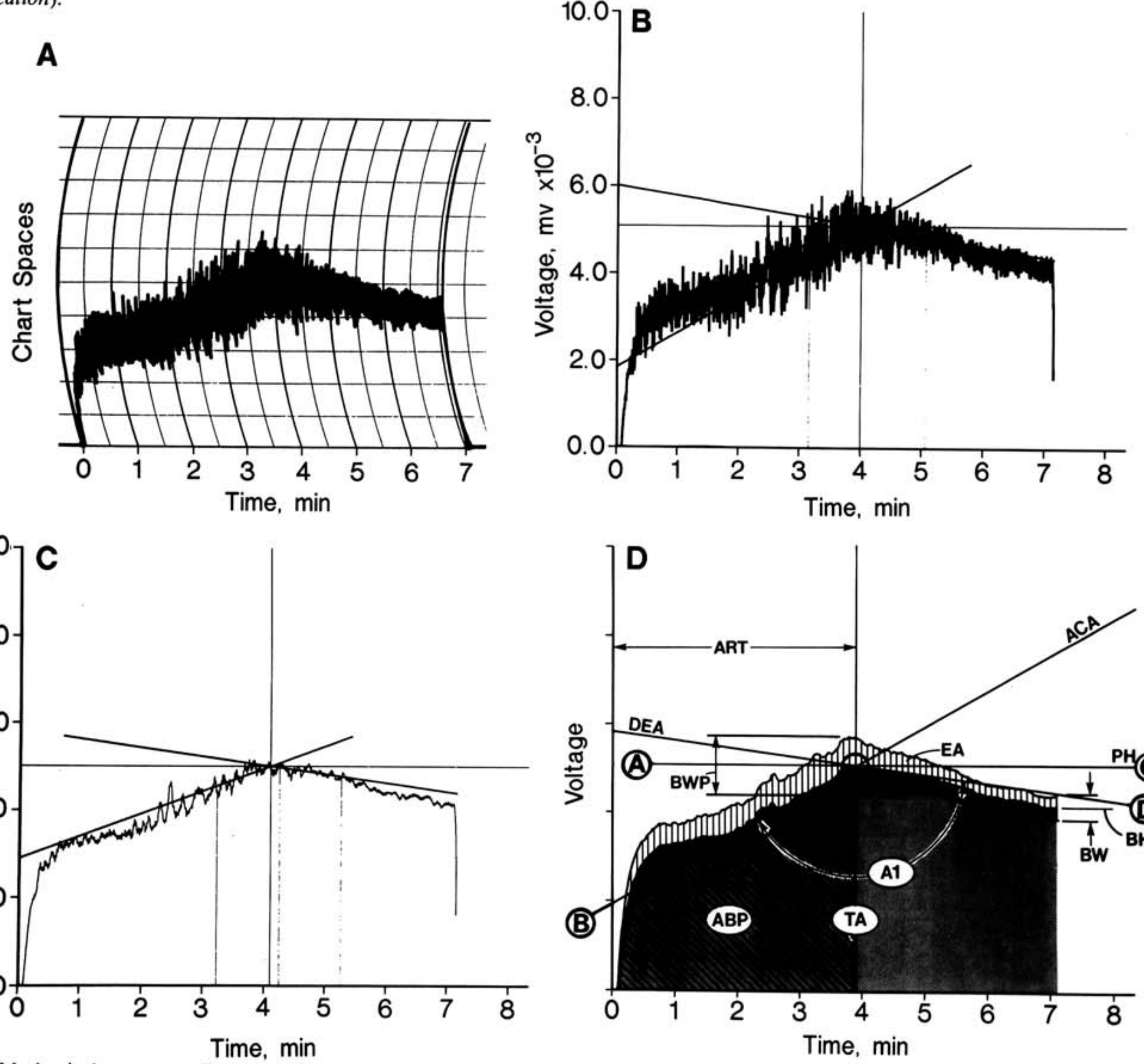

Fig. 3. A, Mechanical pen trace; **B,** computer-generated curve of voltage versus mixing time; **C,** computer curve smoothed with 0.3-sec window; and **D,** computer-generated curve with 11 parameters indicated. **ACA** = angle AOB (degrees), **DEA** = angle COD (degrees), **A1** = angle BOD (degrees), **ART** = arrival time, time to peak (seconds or minutes), **TA** = total area under midpoint of band to 7.0 min (millivolt-seconds), **PH** = peak height at midline of band (millivolts), **ABP** = area under midline of band to peak (millivolt-seconds), **BH** = midpoint of band at 7.0 min (millivolt), **BWP** = bandwidth at peak (millivolts), **EA** = bandwidth area to 7 min (millivolt-seconds).

TABLE II
Analysis of Variance Table for the Effects of Season, Variety, and Protein on Mixograph Measurements[a]

Source of Variation	df	PH	ART	A1	DEA	PHMB	ACA	TA	EA	ABP	BH	BW	BWP	ABPD
Model 1[b]														
Habit	1	11.14**[c]	6,678*	2,143**	519*	2.86**	582*	97.74**	6.16**	0.49	2.71**	0.002	1.28*	0.049*
Variety (habit)	10	0.56**	7,190**	677*	121	0.37**	294*	5.12*	2.25	10.36**	0.27*	0.118*	0.22	0.033**
Residual	24	0.18	1,460	229	118	0.06	129	1.72	0.40	2.54	0.09	0.038	0.22	0.009
R^2		0.82	0.68	0.62	0.37	0.81	0.55	0.80	0.79	0.63	0.77	0.057	0.44	0.062
Model 2														
Protein	1	2.93**	1,178	1,326*	61	0.25*	787*	27.36**	4.97**	0.84	1.48*	0.027	0.61	0.025
Habit	1	0.23	326	14	42	0.30*	89	1.68	0.18	0.13	0.00	0.026	0.00	0.000
Variety (habit)	10	0.09	6,104**	435*	110	0.23**	153	0.97	2.48**	9.14**	0.21**	0.119*	0.17	0.024*
Residual	23	0.06	1,473	181	121	0.06	101	0.60	0.20	2.62	0.03	0.038	0.04	0.009
R^2		0.95	0.69	0.71	0.38	0.84	0.66	0.93	0.90	0.64	0.93	0.058	0.58	0.066

[a] Heading abbreviations are explained in Fig. 3D, except for PHMB = PH minus BH (millivolts) and ABPD = ABP/TA (dimensionless).
[b] Model 1 is without protein, model 2 includes protein.
[c] $*P < 0.05$, $**P < 0.01$.

source of variation was strong enough to be significant by itself. For ART, ABP, BW, APBD, and DEA, adding protein had little (<4%) effect on the R^2 value.

Overall, whereas protein was the major influence on most of the mixograph measurements, there were some differences inherent between the varieties that were not entirely due to protein amounts. Replicate runs need to be made to confirm this or the relationship between parameters and the quality of baked goods, etc. Nevertheless, as described, the modification is simple to construct, indicates directly the bowl position (torque), and requires minimal electronics to condition the signal to a recorder or computer.

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LITERATURE CITED

BRUINSMA, B. L., ANDERSON, P. D., and RUBENTHALER, G. L. 1978. Rapid method to determine quality of wheat with the mixograph. Cereal Chem. 55:732.

FINNEY, K. F., and SHOGREN, M. D. 1972. A ten-gram mixograph for determining and predicting functional properties of wheat flours. Baker's Dig.

HARRIS, R. H., SIBBITT, L. D., and BANASIK, O. 1943. Prediction of loaf volume of hard red spring wheat flours from some properties of mixograms. Cereal Chem. 20:211.

JOHNSON, J. A., SWANSON, C. O., and BAYFIELD, E. G. 1943. The correlation of mixograms with baking results. Cereal Chem 20:625.

RUBENTHALER, G. L., and KING, G. E. 1986. Computer characterization of mixograms and their relationship to baking performance. In: Fundamentals of Dough Rheology. H. Faridi and J. M. Faubion, eds. Am. Assoc. Cereal Chem.: St. Paul, MN.

SWANSON, C. O., and WORKING, E. B. 1933. Testing the quality of flour by the recording dough mixer. Cereal Chem 10:1.

SWANSON, C. O., and JOHNSON, J. A. 1943. Description of mixograms. Cereal Chem. 20:39.

VOISEY, P. W. 1971. Modernization of texture instrumentation. J. Texture Stud. 2:129.

VOISEY, P. W., MILLER, H., and KLOEK, M. 1966a. Electronic dough mixer I. The apparatus. Cereal Chem. 43:408.

VOISEY, P. W., MILLER, H., and KLOEK, M. 1966b. An electronic recording dough mixer II. An experimental evaluation. Cereal Chem. 43:420.

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